Neural and cognitive mechanisms of creativity

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CHAPTER 4

More creative through positive mood? Not everyone!

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ABSTRACT

It is commonly assumed that positive mood improves human creativity and that the neurotransmitter dopamine might mediate this association. However, given the non-linear relation between dopamine and creative performance (Akbari Chermahini & Hommel, 2010), the impact of mood on creativity might depend on a given individual's tonic dopamine level. Indeed, our findings suggest that: the association between tonic dopamine levels and creativity (divergent thinking) follows an inverted U-shape function (with best performance for medium levels); positive and negative mood inductions raise and lower the dopamine level, respectively; so that individuals with low dopamine levels benefit from positive mood more thanindividuals with medium or high levels. This observation challenges the generality of the widely held view that positive mood facilitates creativity.

INTRODUCTION

Creativity is arguablythe most potent human resource both for the advancement of mankind in general and people's individual progress and success in daily life in particular. And yet, the cognitive and neural mechanisms underlying creative behavior are poorly understood.Researchers agree that at least some forms of creativity vary with mood and two recent meta-analyses have concluded that performance in tasks tapping divergent (brainstorm-like) thinking can be reliably improved by inducing positive mood (Baas, De Dreu & Nijstad, 2008; Davis, 2009). This conclusion fits with earlier considerations of Isen (1987), who claimed that positive affect impacts cognitive processing by (1) increasing the number of cognitive elements available for association; (2) defocusing attention so to increase the breadth of those elements treated as relevant to the problem; and (3) increasing cognitive flexibility.

Exactly how positive mood manages to improve creativity is not yet clear, but in approaches that tackle this issue the neurotransmitter dopamine (possibly in concert with other neurotransmitter systems: Cools, Roberts & Robbins, 2008) plays a major role. Notably,Ashby, Isen, and Turken (1999) have pointed out that phasic changes indopamine levels, mood changes, and changes in creativity may be strongly interrelated. Their approach is inspired by insights into theneurobiology of reward,the encounter of which has been shown to induce both positive affect and phasic increasesof dopamine levels (e.g., Beninger, 1991; Bozarth, 1991; Philips, Blaha, Pfaus & Blackburn, 1992; Schultz,1992). Accordingly, Ashby and colleagues (1999) suggest that improved mood states are accompanied by phasic increases in dopaminergic supply provided by frontal and striatal pathways. These phasic increases might facilitate switching from one task set or item to another, thereby increasing cognitive flexibility in creativity task.This scenario is consistent with results fromneural-network modeling (Ashby et al., 1999; Cohen& Servan-Schreiber, 1992) and the observation that divergent-thinking performance interacts with individual differences in the DRD2 TAQ IA gene—which affects receptor density in the striatal dopaminergic pathway (Reuter, Roth, Holve, & Hennig, 2006). Moreover, the personality trait of "seek", which has been claimed to rely on dopaminergic pathways (Panksepp, 1998), has been reported to be positively related to creativity (Reuter et. al., 2005).

To assess the connection between creativity and dopamine more directly, Akbari Chermahini and Hommel (2010) related individual performance in creativity tasks to spontaneous eye-blink rates (EBRs), a well-established clinical marker of the individual dopamine level(Blin et al., 1990; Karson, 1983; Kleven & Koek, 1996). Divergent thinking did in fact covary with EBR but the function relating these two measures was nonlinear and followed an inverted-U shape. That is, individuals with mediumEBRs were performing better than individuals with low or high rates did. If we take EBRs as a marker of the current dopamine level (presumably integrating tonic and phasic levels), this has a number of rather serious implications that we set out to test in the present study.

First, it suggests that increasing the dopamine level by means of a positive-mood induction is likely to facilitate divergent thinking in individuals with low tonic dopamine levels but not necessarily in individuals with medium or high levels. In other words, people with a low pre-experimental EBR would be expected to benefit from positive mood more than people with a medium or high pre-experimental EBR do.[1]

Note that this reasoning holds only if positive-going mood can actually be considered to increase the phasic dopamine level in humans, which is yet to be demonstrated. Accordingly, our second hypothesis was that the experimentally induced positive or negative mood changes should be reflected in corresponding increases or decreases in EBR.

Third, if we take both mood and EBR changes as reflections of phasic dopaminergic changes, the amount ofmood and EBR changes should be systematically related to changes in divergent thinking. That is, elevated mood and increased EBRs should be associated with

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[1] Informal observations from our lab revealed that people with very high EBR levels are rare in our student population and more often than not report to have family members with schizophrenia. This fits with the distribution of EBRs in Akbari Chermahini and Hommel’s (2010) and in the present study, where the EBRs of the majority of participants falls on the left, ascending part of the inverted U-shaped function relating EBR to divergent thinking. If we later in this article distinguish between below- and above-median EBRs, it should therefore be kept in mind that even above-median EBRs in the present study are actually representing medium EBRs in the population. In other words, the present study actually compares individuals with low vs. medium EBRs rather than low vs. high EBRs.

improved performance in divergent thinking, whereas negative-going mood and decreased EBRs would be more likely to be associated with impaired divergent thinking.

We tested these hypotheses in the following way: Participants were first tested on general, pre-experimental mood (for both their general and their current mood state), on performance in divergent thinking, and on their pre-experimental EBR. Then two subgroups of participant underwent a positive-mood and negative-mood induction, respectively, before again being tested on mood, divergent thinking, and EBR.

METHOD

Eighty-one native Dutch students of Leiden University volunteered in exchange for course credit or pay. The study consisted of three phases. First, all participants filled out an inventory assessing their general mood (PANAS) and a mood inventory assessing their current mood state(MI1), before performing a divergent-creativity task (Alternate Uses Task: AUT1); finally, their spontaneous EBR were measured (EBR1). In the second phase, 43 participants received a positive-mood induction while 38 participants received a negative-mood induction. In the third phase, another version of the mood inventory (MI2) was filled out, EBR2 was measured, and another version of the creativity task was performed (AUT2). The order of the two versions of the mood inventory and the creativity task was counter-balanced across participants. EBR2 was measured after mood induction while subject continually was thinking about either happy or sad memory.

Positive and Negative Affect Scales (PANAS)

The PANAS(Watson, Clark, & Tellegen, 1988) is a 20-item self-report mood scale that measures general (“how do you feel generally?”)positive affect (PA) and negative affect (NA). It comprises of 10 positive and 10 negative adjectives rated on a Likert scale from 1 (very little or not at all) to 5 (very or extremely). We used a Dutch version of the scale with high internal consistencies for the PA (Cronbach's alpha=0.84) and the NA (Cronbach's alpha=0.80) subscale (cf., Hill et al., 2005).

Mood Inventory (MI)

Two Dutch versions of a mood inventory (developed by Phillips, Bull, Adams& Fraser, 2002, and similar to the scale of Isen, Daubman & Nowicki, 1987) were used to assess current mood in the first and the third phase of the experiment. Three of the five items of this inventory assess the hedonic quality of affect (Phillips et al., 2002). One version (Cronbach's alpha=0.75) used the following adjective pairs (Dutch words are given in parentheses) to measure valence: happy–sad (*blij-verdrietig*), peaceful–anxious (*verdig-angstig*), and carefree–serious (*zorgeloos-serieus*). The second version (Cronbach's alpha=0.85) used the pairs: positive–negative (*positief-negatief*), calm–uptight (*kalm-opgewonden*), and bright–dispirited (*helder-serieus*). Positive and negative words were presented on the left and right side of a page, respectively. Nine-point Likert scales separated the words of each pair and participants were asked to rate their current mood state (following Phillips et al., 2002). For analytical purposes the mood scores were reversed and then totaled, so that higher scores indicated more positive mood.

Alternate Uses Task (AUT)

Following Guilford (1967), participants were asked to write down as many possible uses for a common household item as they can within 5 min. Two different items were used: *cup*and *pencil*, with the order being balanced across participants. Responses can be scored with respect to four aspects (flexibility, originality, fluency, and elaboration). However, given that flexibility is most strongly and reliably related to EBR measures (Akbari Chermahini & Hommel, 2010) we focused on the flexibility score, which is derived from the number of different categories being used for each item.

Eye Blink Rate (EBR)

A BioSemi ActiveTwo system (BioSemi Inc., Amsterdam) was used to record the EBR. We recorded with two horizontal (one left, one right) and two vertical (one upper, one lower of right eye) Ag-AgCl electrodes, for 6 min eyes-open segments under resting conditions. The vertical electrooculogram (EOG), which recorded the voltage difference between two electrodes placed above and below the left eye, was used to detect eye blinks. The horizontal EOG, which recorded the voltage difference between electrodes placed lateral to the external canthi, was used to measure horizontal eye movements. As spontaneous EBR is stable during daytime but increases in the evening (around 8:30 pm, see Babarto et al., 2000), we never registered after 5 pm. We also asked participants to avoid smoking before the recording. Participants were comfortably sitting in front of a blank poster with a cross in the center, located about 1m from the participant. The participant was alone in the room and asked to look at the cross in a relaxed state to record EBR1. After mood induction (either positive or negative) EBR2 was recorded. The individual EBR was calculated by dividing the total number of eye blinks during the 6-min measurement interval by 6.

Mood Induction

We used the common mental-imagination procedure (e.g., Bodenhausen et al., 1994; Baas et al., 2008; DeSteno et al., 2004; Phillips et al., 2002; Strack et al., 1985) to induce positive and negative mood. Participants were asked to write down a couple of sentences about an event of their life that made them happy(in a calm, relaxed way) or sad(in a calm, non-angry way),respectively, for 5 min. Calmness was emphasized to keep the two emotional states comparable regarding activation and arousal. EBR2 was recorded right after the mood induction; participants were asked to stop writing but to keep thinking about the event during the measurementinterval. The session was completed by filling in the MI2.

RESULTS

Comparability of groups

Aset of independent t-test were conducted to check whether the two experimental groups were comparable before undergoing the mood induction. There was not any hint to any pre-experimental difference between the two groups with respect to either the positive or negative subscale of PANAS, and the hedonic-valence scores computed from the MI1, nor did any of these scales correlate with EBR1, all *p*s>.05. Table 1 provides the relevantinformation about the mood states in two experimental groups and the four subgroups.Interestingly, thelack of a correlation between EBR1 and pre-experimental mood suggests that mood does not depend on the tonic dopamine level but, if anything, on phasic changes.

Table 1: Means and Standard Deviations for Pre-experimental General Mood States (PANAS: positive and negative scales), and Current Mood States (only hedonic valence score) Before (MI1) and After (MI2) Mood Induction in the Two Experimental Groups, and Four Subgroups, as a Function of Low vs. (Relatively) High Pre-Experimental Eye Blink Rate.

State Mood Index		Mood Induction Groups					
		Positive			Negative		
		Total	Low EBR	High EBR	Total	Low EBR	High EBR
		(n=43)	(n=21)	(n=22)	(n=38)	(n=19)	(n=19)
PANAS–PA	M	34.1	33.1	35.1	34.1	33.2	35.1
	S.D.	4.5	4.9	3.9	5.5	4.6	6.1
PANAS-NA	M	16.1	16.2	16.4	16.2	16.4	16.1
	S.D.	4.8	4.9	4.9	6.1	7	5.4
MI1	M	18.06	17.54	18.61	19.86	18.44	20.77
	S.D.	3.08	2.57	3.5	4.05	4.63	3.24
MI2	M	20.95	20.36	21.57	13.36	13.05	13.66
	S.D.	3.06	2.93	3.13	4.7	4.26	5.21

Note: PANAS-PA, PANAS positive affect subscale; PANAS-NA, PANAS negative affect subscale.

Two more sets of independent t-tests assessed whether the groups were comparable with regard to the pre-experimental EBR1 and the flexibility score in the creativity task before the mood induction. Not any significant group difference was detected however, all *p*s >.05.

Manipulation check

Another set of paired-sample t-tests on the hedonic valence score in MI1 and MI2 served to check whether the mood manipulation worked. As expected, participants were significantly more happy after positive-mood induction than before (*M*=20.95 vs. 18.11), $t(42)= 5.74$, $p< 0.001$, $\eta^2= 0.44$, and significantly less happy after negative-mood induction (*M*=13.07 vs.19.65), $t(37)=7.76$, $p<0.001$. $\eta^2= 0.62$.This suggests that the mental-imagery procedure was effective in inducing the respective mood states.

Mood and Creativity

Paired sample t-tests assessed the impact of mood induction on performance in the creativity task by comparing flexibility scores before and after the mood manipulation. As expected, the induction of positive mood enhanced flexibility (*M*=7.1 vs. 5.7), $t(42)=3.26$, $p < 0.01$, $\eta^2= 0.20$. The induction of negative mood reduced flexibility (*M*=5.52 vs. 5.26), but this effect was not significant, $t(37)=0.84$, $p> 0.05$, $\eta^2= 0.02$. The correlation between change in creativity (AUT2-AUT1: flexibility score) and change in mood (MI2-MI: hedonic valence) was positive and reliable, $r = 0.44$, $p < 0.001$, suggesting that the degree of mood change statistically predicts the direction and degree of change in creativity.

Mood and EBR

Paired sample t-test revealed systematic changes in EBR after mood induction:As expected, the induction of positive mood led to a significant increase in EBR (*M*=18.79 vs. 14.1), $t(42)=3.8$, $p< 0.001$, $\eta^2= 0.26$. Negative-mood induction reduced EBR (*M*=16.78 vs.17.39) but this effect was not significant, $t(37)=0.64$, $p> 0.05$, $\eta^2= 0.01$.Moreover, the correlation between change in EBR (EBR2-EBR1) and change in mood (MI2-MI: hedonic valence) was positive and reliable, and the best fit was obtained for a linear function (Figure 1) relating EBR changes to mood changes, $r = 0.35$, $p = 0.003$, suggesting that the degree of mood change was associated with proportional phasic increases and decreases of the individual dopamine level.

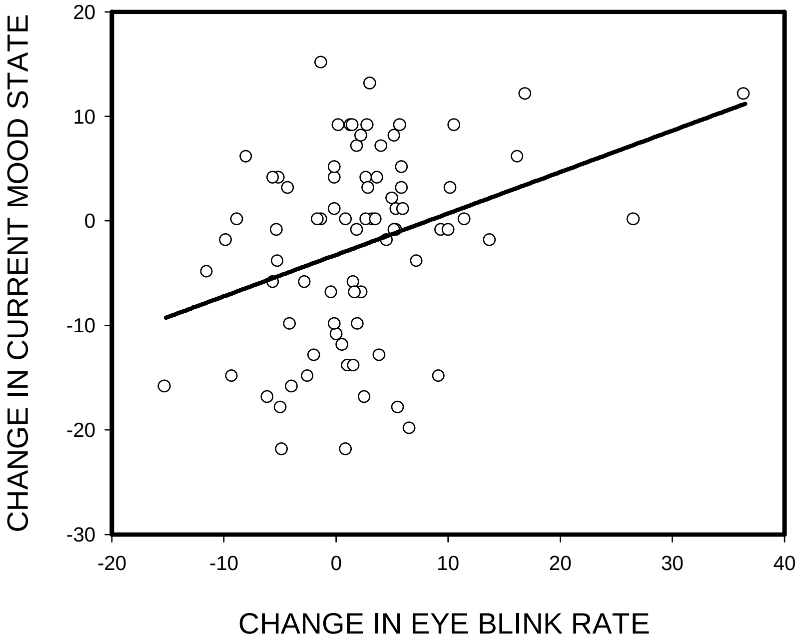

Figure 1: Correlation Between change in Eye Blink Rate (EBR2-EBR1) and Change in Current Mood State (MI2-MI1: hedonic valence) as a Function of Positive and Negative Mood Induction.

Interestingly, the impact of positive mood on EBR was mediated by the pre-experimental EBR level. Participants with a pre-experimentally low (i.e., below-median) EBR showeda pronounced and highly significant increase in EBR after positive mood induction from 7.57 to 14.14, $t(21) = 3.27$, $p = 0.004$, $\eta^2 = 0.34$, whereas participants with a pre-experimentally high (i.e., above-median) EBR only tended to show reliable change in EBR (from 20.9 to 23.5),$t(20) = 2.05$, $p = 0.054$, $\eta^2 = 0.19$.

Creativity and EBR

The relationship between performance in the creativity task (AUT1: flexibility score)and EBR1followed an inverted U-shapedfunction (Figure 2, quadratic fit= 0.36, p=.005), which confirms our previous observations (Akbari Chermahini & Hommel, 2010).The correlation between change in EBR (EBR2-EBR1) and change in creativity performance (AUT2-AUT1: flexibility score) was positive and reliable, $r = 0.19$, $p = 0.047$, suggesting that the degree of flexibility change was proportional to the phasic increases and decreases of the individual dopamine level.

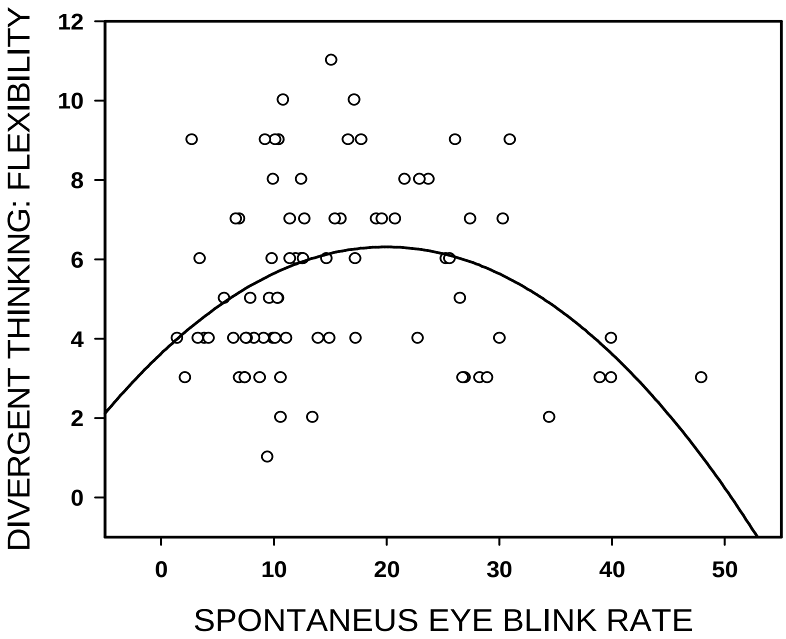

Figure 2: Performance in the creativity task (flexibility score) as a function of spontaneous eye blink rate (EBR) per min. Regression line for best (quadratic) fit.

Interactions between Mood, Creativity, and EBR

Importantly, the experimentally induced mood changes had the predicted impact on EBR and creativity: Individuals were becoming more creative to the degree that the positive-mood induction increased their EBR, r=.29, p=.03(Figure 3, line: P), and tended to become less creative to the degree that the negative-mood induction decreased their EBR, r=-.23, p=.09 (Figure 3, line: N).This pattern suggests that the extent of phasic increases and decreases of dopamine systematically predicts the degree of facilitation or impairment of creative behavior, respectively.

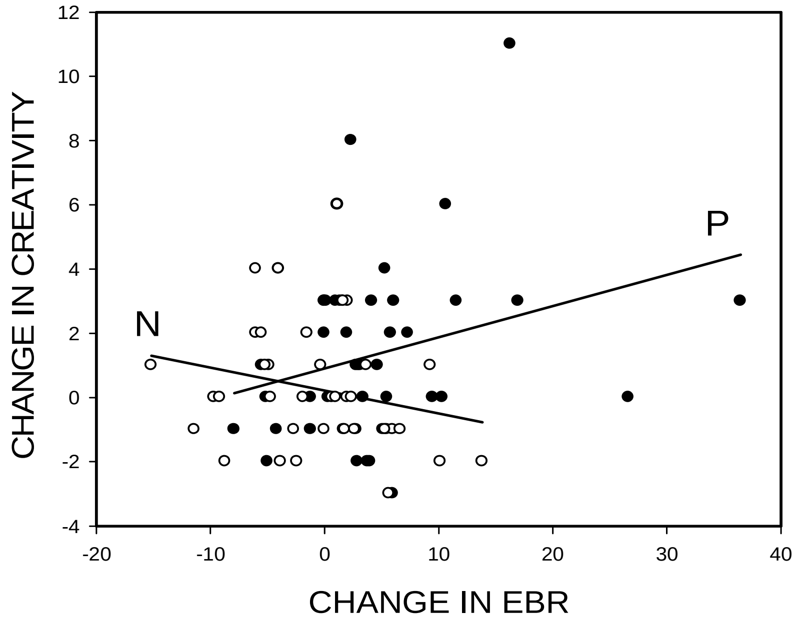

Figure 3: Mood-induced change in creativity performance (creativity score post minus creativity score pre mood induction) as a function of the mood-induced change in spontaneous eye blink rates (EBRs). Empty circles and regression line N for participants with negative-mood induction; filled circles and regression line P for participants with positive-mood induction.

Again, the mood-induced effect was contingent on the pre-experimental EBR1. As Figure 4a shows, positive mood increases EBR mainly in low (i.e., below-median) EBR1 individuals but not so much in high-EBR1 participants—even though the distribution of EBRs (see Figure 2) does not suggest that this might be due to a ceiling effect. Likewise, as shown in Figure 4b, the induction of positive mood improved performance in the creativity task onlyin low-EBR1 individuals (from 5.8 to 8.0 categories, $t(21)=3.54$, $p=.002$, $\eta^2=0.37$)but not in high-EBR1 participants (5.7 vs. 6.1), $t(20)=.87$, $p=.4$).

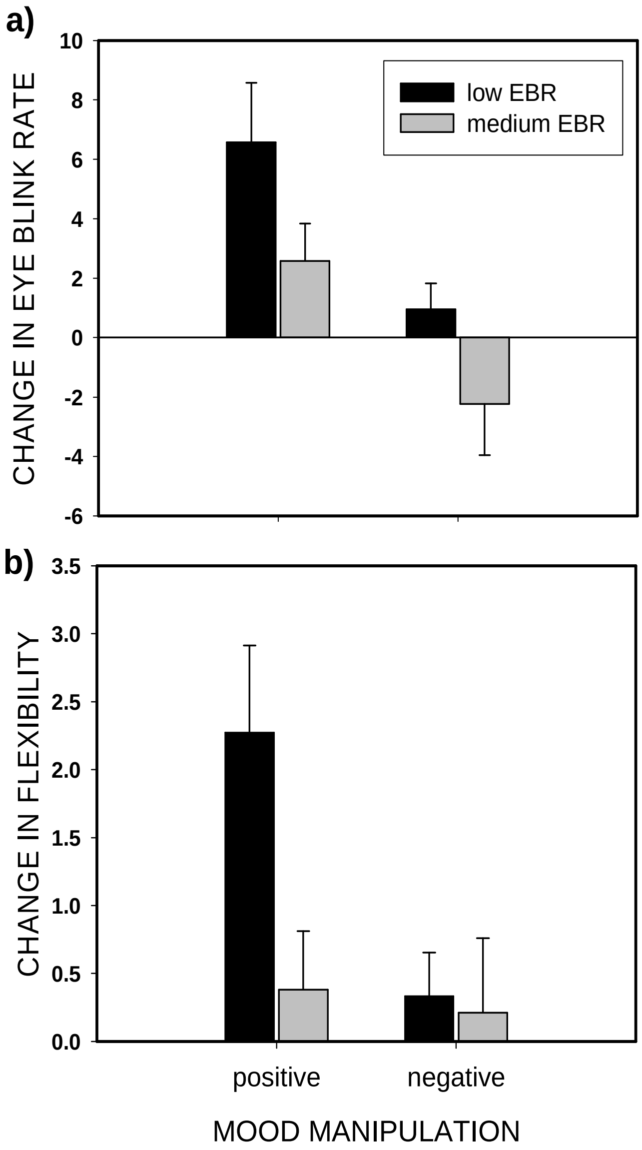

Figure 4: Change in spontaneous Eye Blink Rate (EBR) (**a**), and performance in creativity task (divergent thinking: flexibility) (**b**), as a function of mood induction (either positive or negative), and individual's EBR level (low and medium)

DISCUSSION

The aim of the present study was to investigate the relationship between mood, creativity, and phasic dopamine changes as reflected in EBRs. The mood induction manipulation work as expected, even though the induction of positive mood was more effective than the induction of negative mood. As implied by our second hypothesis, positive- and negative-going mood changes were accompanied by systematic increases and decreases of EBR, respectively. This suggests that EBR is a sensitive measure of mood-related phasic dopaminergic changes. Moreover, we were able to fully replicate the inverted U-shaped function relating flexibility in divergent thinking to pre-experimental EBR, first reported by Akbari Chermahini and Hommel (2010). If we assume that pre-experimental EBR (i.e., EBR1) reflects the individual tonic dopamine level, this replication confirms that EBR is a reliable index of tonic dopamine levels as well.

As implied by our third hypothesis, all three factors under investigation were systematically related to each other—even though, again, these relations were more pronounced in the context of positive-mood induction. Flexibility in divergent thinking was facilitated or tended to be impaired through the induction of positive or negative mood, respectively, and the degree of this improvement was predicted by the individual degree to which the mood induction manipulation was successful. Likewise, EBR increased or tended to decrease through the induction of positive or negative mood, respectively, and the degree of this phasic change was again predicted by the degree to which the mood induction manipulation was successful. Finally, the positive and negative changes in EBR predicted the increase or decrease of flexibility in divergent thinking, suggesting that phasic increases and decreases in dopamine facilitated or impaired divergent creativity, respectively. Hence, all three factors seem to be related to each other exactly as predicted, and even the asymmetry between the effects of the positive- vs. negative-mood induction is equally reflected in all three measures.

According to our first hypothesis, this interrelationship—together with the fully replicated inverted U-shaped relationship between EBR and creativity—suggest that individuals with low tonic dopamine levels might benefit more from the induction of positive mood than individuals with medium or high levels do. Indeed, mood-induced improvement of divergent thinking was only observed in individuals with a pre-experimentally low EBR and a presumably corresponding low tonic dopamine level. Not only does this fit with the nonlinear relation between EBR in divergent thinking reported by Akbari Chermahini and Hommel (2010), it is also likely to explain why unreliable findings and failures to replicate are still abundant in studies on the connection between mood and creativity (Baas et al., 2008; Davis, 2009).

Taken together, our findings support the assumption that phasic changes in dopamine levels provide the common currency underlying the relationship between mood and creativity, as suggested by Ashby et al. (1999) and others, and they provide the hitherto most direct evidence for the underlying interrelationship between mood, creativity, and dopamine. In particular, elevated mood seems indeed to increase the dopamine level and to improve creativity as assessed by our divergent-thinking task. At the same time, however, there is evidence that the reliability and, presumably, the direction of the impact of mood and associated phasic dopamine changes depend on the individual tonic dopamine level (but not the basic mood level!). This questions the generality of claims regarding the positive impact of mood on creativity and calls for closer consideration of individual differences. As our findings demonstrate, better mood may or may not facilitate (and may in some cases even impair) creative performance of a given individual. Depending on the specific characteristics of a given sample, this complication may well conceal the true connections between creativity, mood, and dopaminergic activity in empirical studies and applied settings.

In the light of our findings, a number of further questions present themselves. For instance, it remains to be seen whether a comparable interrelationship exists between mood, dopamine, and convergent thinking—which apparently relates to tonic dopamine levels in different, and in some sense opposite, ways than divergent thinking does (Akbari Chermahini & Hommel, 2010). Recently we observed that engaging in divergent thinking leads to more negative mood (Akbari Chermahini & Hommel, 2011), which would fit with this expectation. Moreover, it seems important to clarify the functional relationship between mood and phasic dopaminergic changes. After all, mood is a concept that relates to a personal level of description and relates to a person having and experiencing it. In contrast, changes in dopaminergic activity refer to the systems level of description, which may or may not correspond to personal-level concepts in a one-to-one fashion. Hence, it would be important to understand whether and to what degree dopaminergic changes are the neural reflection of being in a particular mood, or whether they are mere byproducts of particular mood states.

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